Technique and Patient Selection Criteria of Right Anterior Mini-Thoracotomy for Minimal Access Aortic Valve Replacement

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Abstract: Aortic valve stenosis has become the most prevalent valvular heart disease in developed countries, and is due to the aging of these populations. The incidence of the pathology increases with growing age after 65 years. Conventional surgical aortic valve replacement through median sternotomy has been the gold standard of patient care for symptomatic aortic valve stenosis. However, as the risk profile of patients worsens, other therapeutic strategies have been introduced in an attempt to maintain the excellent results obtained by the established surgical treatment. One of these approaches is represented by transcatheter aortic valve implantation. Although the outcomes of high-risk patients undergoing treatment for symptomatic aortic valve stenosis have improved with transcatheter aortic valve replacement, many patients with this condition remain candidates for surgical aortic valve replacement. In order to reduce the surgical trauma in patients who are candidates for surgical aortic valve replacement, minimally invasive approaches have garnered interest during the past decade. Since the introduction of right anterior thoracotomy for aortic valve replacement in 1993, right anterior mini-thoracotomy and upper hemi-sternotomy have become the predominant incisional approaches among cardiac surgeons performing minimal access aortic valve replacement. Beside the location of the incision, the arterial cannulation site represents the second major landmark of minimal access techniques for aortic valve replacement. The two most frequently used arterial cannulation sites include central aortic and peripheral femoral approaches. With the purpose of reducing surgical trauma in these patients, we have opted for a right anterior mini-thoracotomy approach with a central aortic cannulation site. This protocol describes in detail a technique for minimally invasive aortic valve replacement and provides recommendations for patient selection criteria, including cardiac computer tomography measurements. The indications and limitations of this technique, as well as its alternatives, are discussed.

DOI: https://doi.org/10.3791/57323

Originally published at:
Tavakoli, Reza; Leprince, Pascal; Gassmann, Max; Jamshidi, Peiman; Yamani, Nassrin; Amour, Julien; Lebreton, Guillaume (2018). Technique and Patient Selection Criteria of Right Anterior Mini-Thoracotomy for Minimal Access Aortic Valve Replacement. Journal of Visualized Experiments (Jove), (133):e57323.
DOI: https://doi.org/10.3791/57323

Video Article

Technique and Patient Selection Criteria of Right Anterior Mini-Thoracotomy for Minimal Access Aortic Valve Replacement

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URL: https://www.jove.com/video/57323
DOI: doi:10.3791/57323

Keywords: Medicine, Issue 133, Right Anterior, Mini-Thoracotomy, Aortic Valve Replacement, Aortic Cannulation Site, Heart Disease, Surgical Treatment

Date Published: 3/26/2018

Citation: Tavakoli, R., Leprince, P., Gassmann, M., Jamshidi, P., Yamani, N., Amour, J., Lebreton, G. Technique and Patient Selection Criteria of Right Anterior Mini-Thoracotomy for Minimal Access Aortic Valve Replacement. *J. Vis. Exp.* (133), e57323, doi:10.3791/57323 (2018).

Abstract

Aortic valve stenosis has become the most prevalent valvular heart disease in developed countries, and is due to the aging of these populations. The incidence of the pathology increases with growing age after 65 years. Conventional surgical aortic valve replacement through median sternotomy has been the gold standard of patient care for symptomatic aortic valve stenosis. However, as the risk profile of patients worsens, other therapeutic strategies have been introduced in an attempt to maintain the excellent results obtained by the established surgical treatment. One of these approaches is represented by transcatheter aortic valve implantation. Although the outcomes of high-risk patients undergoing treatment for symptomatic aortic valve stenosis have improved with transcatheter aortic valve replacement, many patients with this condition remain candidates for surgical aortic valve replacement. In order to reduce the surgical trauma in patients who are candidates for surgical aortic valve replacement, minimally invasive approaches have garnered interest during the past decade. Since the introduction of right anterior thoracotomy for aortic valve replacement in 1993, right anterior mini-thoracotomy and upper hemi-sternotomy have become the predominant incisional approaches among cardiac surgeons performing minimal access aortic valve replacement. Beside the location of the incision, the arterial cannulation site represents the second major landmark of minimal access techniques for aortic valve replacement. The two most frequently used arterial cannulation sites include central aortic and peripheral femoral approaches. With the purpose of reducing surgical trauma in these patients, we have opted for a right anterior mini-thoracotomy approach with a central aortic cannulation site. This protocol describes in detail a technique for minimally invasive aortic valve replacement and provides recommendations for patient selection criteria, including cardiac computer tomography measurements. The indications and limitations of this technique, as well as its alternatives, are discussed.

Video Link

The video component of this article can be found at https://www.jove.com/video/57323/

Introduction

Among heart valve lesions diagnosed as hemodynamically relevant and clinically receiving particular attention, aortic valve stenosis is the most common valvular pathology in the United States and developed countries[1,2]. In the Cardiovascular Health Study, 2% of patients had frank aortic stenosis, with a clear increase in prevalence with growing age: 1.3% in patients aged 65-75 years, 2.4% in those aged 75-85 years, and 4% in patients older than 85 years[1]. For symptomatic patients presenting with severe aortic valve stenosis, aortic valve replacement is a Class I recommendation in the guidelines of the American Heart Association for the management of patients with valvular heart disease[3].

Conventional surgical aortic valve replacement through median full sternotomy (FS) has been established as the gold standard for treating aortic valve stenosis with excellent results in terms of morbidity and mortality[4]. These results have encouraged the extension of therapeutic indications to older patients and patients with a higher risk profile. A number of treatment strategies have been implemented in these patient subsets to maintain the same good results achieved by conventional surgical aortic valve replacement in the general population. Among these alternative treatment modalities, transcatheter aortic valve implantation (TAVI) was introduced in 2002 by Cribier and colleagues[5]. Performed initially in moribund patients, TAVI has rapidly emerged as the treatment of choice for patients with severe aortic stenosis who are not suitable for conventional surgical aortic valve replacement[6,7], or as a less invasive approach for surgery for patients at high risk[8,9].

Despite the improved outcomes of TAVI in selected patient subsets, many patients with symptomatic aortic valve stenosis are still candidates for surgical aortic valve replacement. In these patients, FS aortic valve replacement is the most frequently used approach by cardiac surgeons. Nevertheless, various 'minimally invasive' techniques have been developed with the rationale of reducing surgical trauma[10]. All these minimal-access techniques have aimed at improving patient comfort by reducing post-operative pain and accelerating patient recovery by shortening the hospital stay and potentially saving global costs[10]. Among minimally invasive incisional approaches upper hemi-sternotomy (UHS) and right anterior mini-thoracotomy (RAMT) have become the predominant techniques reported in the literature[11]. Right anterior mini-thoracotomy for aortic valve replacement was initially reported by Benetti *et al.*[12], and upper hemi-sternotomy was first described by several authors[11]. In addition to incisional alternatives, two arterial perfusion strategies are currently used: i) peripheral femoral arterial cannulation, which is more frequently employed than ii) central aortic cannulation.

In spite of reported improvement in patient outcomes following minimally invasive aortic valve replacement, concerns about the disadvantages of restricted operative field and peripheral arterial perfusion strategies[13] lead many cardiac surgeons to not let their patients benefit from potential advantages of minimal access approaches for aortic valve replacement. The goal of this protocol is to describe in detail this technique of minimally invasive aortic valve replacement through a right anterior mini-thoracotomy without rib resection/fracture, and with central aortic cannulation for arterial perfusion. By following this protocol, a larger number of cardiac surgeons can perform right anterior mini-thoracotomy for aortic valve replacement in certain patient groups. Patient selection and limitations of the technique are discussed. Early results are compared to those of a cohort of patients undergoing isolated aortic valve replacement by full sternotomy.

Protocol

The protocol follows our institutional guidelines of the human research ethics committee.

1. Patient Selection (Table 1)

1. Identify patients necessitating isolated aortic valve replacement[14].
2. Select among these patients a subgroup without major chest deformities (Kypho-scoliosis), previous history of irradiation or surgery of the right hemi-thorax, need for emergency operation, and operation for active endocarditis.
3. Perform a chest computed tomography (CT) scan to exclude patients with ascending aortic aneurysm ≥4.5 cm.
4. Make the final decision according to the measurements provided by the chest CT (**Figure 1** and **2** and **Table 1**). Choose between the second or third intercostal space, based on closer distances to the aortic cannulation site and the aortic annulus.

2. Preparation for Surgery

1. Prepare the patients for surgery following the institutional guidelines and recommendations for adult cardiac surgery patients, as previously described[14].
2. Place the external defibrillator pads on the back and left chest anteriorly prior to draping.

3. Surgery

1. Access to the heart through a right anterior mini-thoracotomy
    1. Incise the skin transversally over 8 cm with an 18-blade knife over the chosen intercostal space, starting 1 cm to the right of the right sternal edge.
    2. Cut the pectoralis and the superficial layers of the intercostal muscles using the electrocautery. To avoid injury to the right lung, enter the right pleura first with Metzenbaum scissors. Then enlarge the opening of the intercostal muscles with electrocautery.
    3. Preserve the right internal thoracic pedicle by freeing it from the fascia and soft tissue around it using Metzenbaum scissors.
    4. Insert the soft tissue retractor into the right pleura and fix it onto the wound. Take care not to injure the right internal thoracic pedicle.
    5. Place the minimal access retractor over the soft tissue retractor and open it gently and gradually.
    6. Grab the cranially overlying fat with Carpentier forceps and cut it with electrocautery. Take care not to injure the right phrenic nerve.
    7. Open the pericardium over the right atrium with electrocautery and place 2/0 polyglactin stay sutures on both sides of the opening in order to spread the pericardium.
    8. Continue opening the pericardium cranially over the ascending aorta and caudally over the right atrium. Place 2/0 polyglactin stay sutures on both sides of the opening to spread the pericardium.
    9. Check the distal pericardial reflection line over the ascending aorta and the basis of the aortic root to prepare for the placement of the aortic cannulation purse-strings.
    10. Verify the anatomy of the right superior pulmonary vein for the placement of the left ventricular vent.
    11. To expose the distal part of the ascending aorta, gently push down the ascending aorta using a peanut gauze mounted on an Allis clamp.
    12. Place the first purse-string for aortic cannulation just below the distal pericardial reflection line over the ascending aorta using 4/0 polypropylene suture. Complete the preparation for aortic cannulation by adding a second purse-string around the first one using 4/0 polypropylene suture.
    13. Give 300 I.U. of heparin/kg (concentration 5,000 U/mL) through the IV line.

2. Connect the patient to the cardiopulmonary bypass
    1. First puncture the right femoral vein and place the guidewire through the needle into the vein. Enlarge the skin opening with an 11-blade knife. Dilate the puncture site with successive dilators and introduce percutaneously the femoral venous cannula over the guidewire under transesophageal echocardiographic control (**Figure 3**).
    2. Gently push down the ascending aorta using a peanut gauze mounted on an Allis clamp and puncture the ascending aorta in the middle of the purse-strings. Cannulate the aorta over the guidewire.
    3. Start the cardiopulmonary bypass and cool down the patient to 30 °C (**Figure 4**). To improve the venous return, let the perfusionnist apply assisted negative pressure of -50 mmHG.

    4. Gently push the superior vena cava towards the left side and place a purse-string on the right upper pulmonary vein with a 4/0 polypropylene monofilament suture. Insert the left ventricular vent through the purse-string to unload the left heart.

3. Prepare for valve resection and replacement
    1. Cross-clamp the ascending aorta just below the aortic cannula using a flexible clamp with a retractable rigid shaft.
    2. Perform an inverted-L aortotomy parallel and at the level of the sino-tubular junction, extending to the non-coronary Valsalva sinus. Retract the inferior ridge of the aortotomy with an Allis clamp.
    3. In case of aortic regurgitation, deliver the antegrade crystalloid cardioplegia directly into the coronary ostia.
    4. Extend the aortotomy through the non-coronary sinus to 1 cm above the aortic annulus. Check the left and right coronary ostia.
    5. Place a 5/0 polypropylene suture on the inferior ridge of the aortotomy and fix it superficially to the anterior aspect of the right ventricle to improve the exposure of the aortic valve.
    6. Place another 5/0 polypropylene suture on the superior ridge of the aortotomy and fix it superficially to the pericardium to improve the exposure of the aortic valve.
    7. Grab in turn the right, non-coronary, and left coronary cusp with endo-forceps and excise them with endo-scissors. Check the mitral valve through the aortotomy.
    8. Use commercially available valve sizers to determine the labeled size of the valve to be inserted. Choose a sizer which comfortably passes through the aorto-ventricular junction.
    9. Place the first braided polyester 2/0 with pledget U-suture on the commissure between the left and right coronary sinuses, using an endo-needle holder. Pass the suture from the ventricle up so that the pledget is on the ventricle side.
    10. Continue the placement of the braided polyester 2/0 with pledget U-sutures clockwise to complete the right coronary sinus.
    11. Place clockwise braided polyester 2/0 with pledget U-sutures on the non-coronary sinus.
    12. Complete the annulus sutures by placing counter-clockwise braided polyester 2/0 with pledget U-sutures on the left coronary sinus, starting at the commissure between the right and left coronary sinuses.
    13. Pass the braided polyester 2/0 sutures onto the sewing ring of the valve prosthesis using a Ryder needle holder.
    14. Slide down the valve prosthesis and remove the valve holder. Tie the sutures and check for any gap between them and the aortic annulus. Verify that the left and right coronary ostia are unobstructed.
    15. Cut the tied sutures using Metzenbaum scissors. Remove the 5/0 exposure sutures on the inferior and superior ridge of the aortotomy.
    16. Close the aortotomy by two 5/0 polypropylene running hemi-sutures. Place the first one on the nadir of the aortotomy in the non-coronary sinus and tie it. Then come up to the angle of inverted L-aortotomy. Put the end of the suture under slight tension.
    17. Continue the closure of the aortotomy by the second 5/0 polypropylene running hemi-suture starting on the left end and coming towards the right side to meet the end of the first hemi-suture. Tie the two ends together and cut them.
    18. Place the ventricular pacing wires on the right ventricle before unclamping the aorta.
    19. Let the operating table tilt in the Trendelenburg position. Reduce the pump flow to 50% of the full flow. Under gentle aspiration of the left ventricular vent, slowly remove the aortic cross-clamp[14].
    20. Resume the full flow of the cardio-pulmonary bypass. Check the hemostasis of the aortotomy closure. Remove the left ventricular vent and tie its purse-string. Check for hemostasis.
    21. Rewarm the patient to 37 °C. Separate the patient from the cardio-pulmonary bypass. When a stable blood pressure is reached, neutralize the heparin by a protamine-infused IV in a 1:1 ratio (3 mg/kg corresponding to 300 U/kg of heparin)[14].
    22. Prepare for removal of the aortic cannula by tying down the first purse-string. Let the assistant gently remove the aortic cannula and finish tying the purse-strings.
    23. Double-secure the aortic cannulation site with a figure of eight 4/0 polypropylene suture. Cut the sutures.
    24. Remove the femoral venous cannula and secure the hemostasis by manual compression for 20 min.
    25. Place one pericardial and one right pleural chest tube. Adapt the pericardium with three loosely tied braided 2/0 polyglactin sutures.
    26. Adapt the ribs with two braided 0 polyglactin sutures. Close the wound in layers in a standard fashion.

4. Post-Operative Patient Care

1. Following the transfer to the intensive care unit, provide the patient with standard post-operative care for cardiac surgical operations[14].

Representative Results

Statistical analysis is done for continuous variables (presented as means ± SD) in **Table 2**, **Table 3,** and **Table 4** using the non-parametric Mann Whitney test. Categorical variables are presented as percentages in **Table 2**, **Table 3,** and **Table 4**, and are compared by the Chi-square test. The statistical analyses are performed using commercially available software, with a statistical significance threshold set at $p<0.05$.

Table 2 depicts patient characteristics. Aortic valve replacement was done according to the described protocol of right anterior mini-thoracotomy in 196 patients who fulfilled the selection criteria (**Table 1**). Patient characteristics were similar to 171 patients undergoing aortic valve replacement through full sternotomy during the same period. The adoption of the approach was dictated by the choice of the patient, and fulfillment of the selection criteria, including technical feasibility according to the CT measurements (**Table 1**).

Intra operative data are shown in **Table 3**. Based on the pre-operative planning CT, access to the pleural space and the heart was secured through the third intercostal space in 80%, and the second in 20%, of the patients. In one patient, after the start of the cardio-pulmonary bypass, increasing perimeter of the abdomen and volume loss was observed. With the suspicion of an abdominal problem, a laparotomy was performed and an iatrogenic tear in the iliac vein of the percutaneously cannulated side was repaired. In order to shorten the cardiac and global operative times, the incision was extended by a transverse sternotomy and the aortic valve replacement performed afterwards in standard manner. The patient did well post-operatively. The data from this patient are included in the right mini-thoracotomy group. As expected, compared to the full sternotomy approach, a right anterior mini-thoracotomy necessitated significantly longer ischemic, cardio-pulmonary, and operative times. The proportion of biological versus mechanical valve substitutes did not differ between the groups.

Table 4 demonstrates early post-operative outcomes. In spite of longer operation times, with the exception of a peripheral cannulation complication, right anterior mini-thoracotomy did not increase the rate of major adverse cardiovascular and cerebrovascular events in comparison to full sternotomy incision. Patients undergoing right anterior mini-thoracotomy tended to be extubated earlier and stayed for a shorter period in the intensive care unit than those operated through full sternotomy, although the differences were not statistically significant. However, compared to full sternotomy, right anterior mini-thoracotomy significantly reduced the need for pain medication and transfusion requirements, the incidence of new onset atrial fibrillation and deep wound infection as well as the global length of hospital stay. In addition, patients reported great satisfaction with the cosmetic results (**Figure 5**).

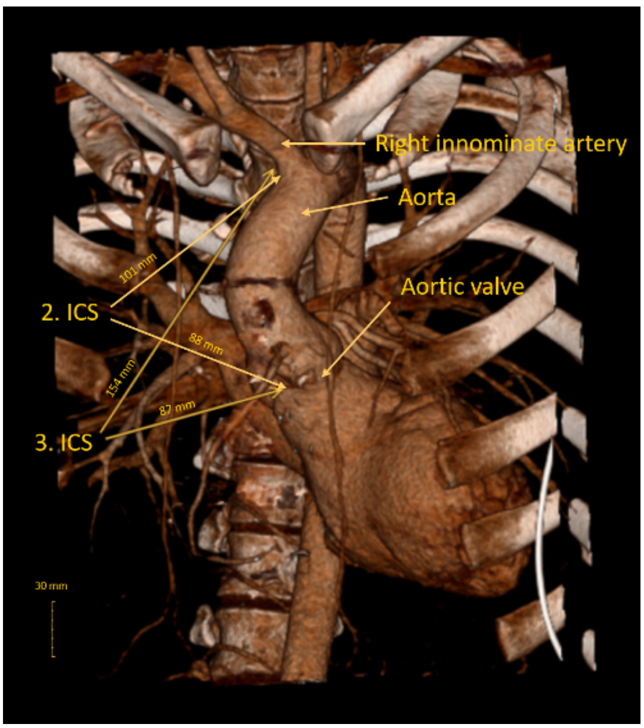

Figure 1:**3-D chest CT reconstruction for pre-operative planning.** Measurements from the mid-clavicular line to the aortic cannulation site (origin of the right innominate artery) and to the aortic valve of the second and third intercostal spaces (ICS) are reported on this image (1 mm in scale = 2.9 mm). In this case, the second ICS is chosen for incisional approach of the mini-thoracotomy while with comparable distances to the aortic valve, the distance to the cannulation site is shorter for the second compared to the third ICS. Please click here to view a larger version of this figure.

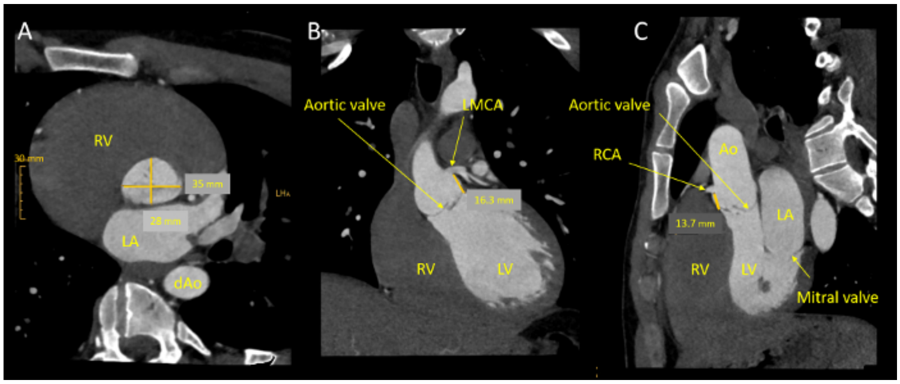

Figure 2: CT measurements for pre-operative planning from the same patient as in Figure 1. (**A**) Annulus sizing. The largest and shortest aortic annulus are both greater than the 20 mm criterium for selection of the patients given in Table 1. **(B**) Distance from the left coronary ostium to the aortic annulus. This distance is greater than 12 mm criterium for selection of the patients given in Table 1. (**C**) Distance from the right coronary ostium to the aortic annulus. This distance is greater than 12 mm criterium for selection of the patients given in Table 1 (1 mm in scale = 2.9 mm). CT measurements of this patient fulfills the CT criteria for selection of the patients for right anterior mini-thoracotomy with pleural entry in the second ICS. RV = right ventricle, LA = left atrium, dAo = descending Aorta, LMCA = left main coronary artery, LV = left ventricle, RCA = right coronary artery, Ao = ascending aorta. Please click here to view a larger version of this figure.

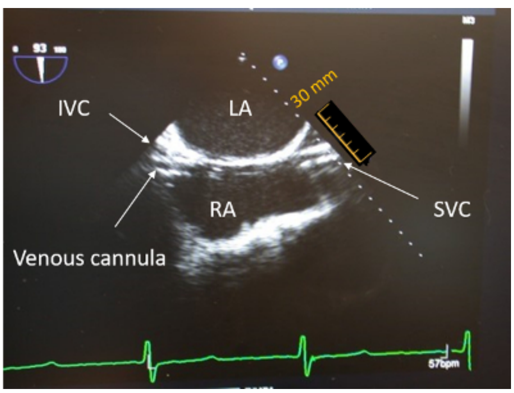

Figure 3: Bi-atrial view by transesophageal echocardiography. The venous cannula is inserted percutaneously through the right femoral vein and placed through the inferior vena cava (IVC) up to the origin of the superior vena cava (SVC) (1 mm in scale = 2.9 mm). LA = left atrium, RA = right atrium. Please click here to view a larger version of this figure.

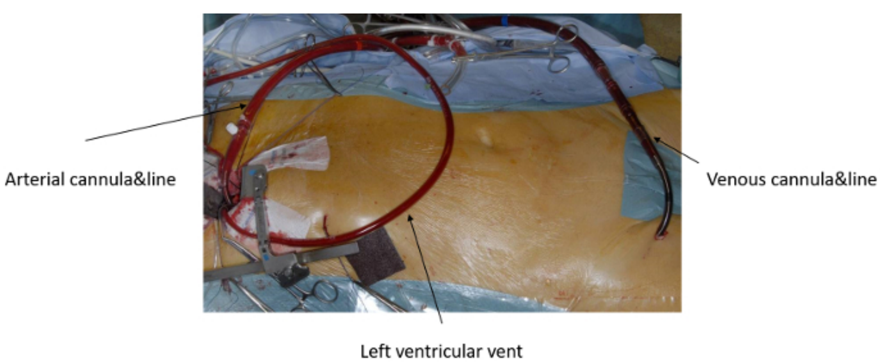

Figure 4: Global view of the cardiopulmonary set-up. The head of the patient is to the left of the picture. Please click here to view a larger version of this figure.

Figure 5: Wound cosmetic. One week after aortic valve replacement through right anterior mini-thoracotomy, the general appearance of the wound is satisfactory. Please click here to view a larger version of this figure.

Absence of:	
chest deformities	
previous right hemi-thorax surgery or irradiation	
aneurysm of the ascending aorta	
emergency operation	
active endocarditis	
Optimal measurements calculated from chest CT	
Intercostal space to aortic valve	< 120 mm
Intercostal space to aortic cannulation site*	< 120 mm
Aortic valve annulus diameter	> 20 mm
Right coronary ostium to aortic valve annulus	> 12 mm
Left coronary ostium to aortic valve annulus	> 12 mm
* Origin of the right innominate artery	

Table 1: Selection criteria for right anterior mini-thoracotomy for isolated aortic valve replacement. After exclusion of patients with major chest deformities, previous right hemi-thorax irradiation or surgery and ascending aortic aneurysms, optimal measurements provided by chest CT allow the selection of the patient for the procedure and the choice of intercostal space for incision.

	Right anterior mini-thoracotomy	Full sternotomy	p value
N	196	171	
Age, years	70±10	68±13	0.26
LVEF < 0.35 (%)	2 (1)	4 (2.3)	0.2
Hematocrit %	38.9±2	37.2±1.6	0.09
Native valve disease			0.16
AS	155	135	
AI	34	27	
AS+AI	7	9	
COPD (%)	13 (6.6)	14 (8.2)	0.8
CVD (%)	17 (8.7)	16 (9.4)	0.9
PVD (%)	10 (5.1)	11 (6.4)	0.14
Diabetes mellitus (%)	29 (14.8)	18 (10.5)	0.42
Arterial hypertension (%)	91 (46)	105 (61)	0.27
CHF (%)	3 (1.5)	8 (4.7)	0.26
Euroscore*	3.8±2.0	2.6±2.4	0.7
LVEF: left ventricular ejection fraction			
AS: aortic stenosis			
AI: aortic insufficiency			
COPD: chronic obstructive pulmonary disease			
CVD: cerebro-vascular disease			
PVD: peripheral vascular disease			
CHF: congestive heart failure			
* Reference 15			

Table 2: Patients' characteristics. The pre-operative condition of the patients undergoing right anterior mini-thoracotomy is comparable to that of patients operated by a full sternotomy approach.

	Right anterior mini-thoracotomy	Full sternotomy	p value
N	196	171	
Operative time (min)	274±60	209±48	0.0001
CPB time (min)	157±36	110±27	0.0001
Cross-clamp time (min)	108±23	62±15	0.0001
Biological valve (%)	161 (82)	121 (71)	0.09
CPB: cardiopulmonary bypass			

Table 3: Intra-operative data. Operation times and type of the valve substitute of the two cohorts of right anterior mini-thoracotomy and full sternotomy approaches.

	Right anterior mini-thoracotomy	Full sternotomy	p value
N	196	171	
Early mortality (%)	3 (1.5)	3 (1.8)	0.1
Re-op. for bleeding (%)	4 (2)	4 (2.3)	0.6
Peri-op. MI (%)	1 (0.5)	2 (1.2)	0.3
Stroke (%)	5 (2.6)	6 (3.5)	0.7
Ventilation time (h)	10.2±6.3	14.4±20	0.09
ICU stay (d)	2±3.3	3.7±14	0.4
New onset Afib (%)	35 (18)	51 (30)	0.02
RBC's (pack/patient)	1.6±2.8	2.1±2.1	0.002
MS (mg/day)*	39.7±22.8	52.5±26.3	0.007
Deep wound infection (%)	0 (0)	2 (1.2)	0.02
Hospital stay (d)	8.2±2.7	10.2±7.3	0.04
MI: myocardial infarction			
ICU: intensive care unit			
Afib: atrial fibrillation			
RBC: Red blood cells			
MS: Morphine sulfate for the first 5 post-operative days			
* for the first 3 days			

Table 4: Early outcomes. In spite of longer operation times, right anterior mini-thoracotomy resulted in better early outcomes without increasing major adverse events.

Discussion

In this protocol, we describe in detail the technique of right anterior mini-thoracotomy for isolated aortic valve replacement, and highlight the patient selection criteria for this procedure. As for any other therapeutic intervention, proper patient selection is the key to successful accomplishment of the procedure. The optimal CT measurements for consideration of patients for this technique are precisely described in this protocol, and are based on experience and consider the extensive work of Dr. Glauber and coworkers in this field[10]. These optimal CT measurements add some valuable criteria, *i.e.*, the annulus size, distances of the coronary ostia from the aortic annulus, to the recommendations of Glauber *et al.,* who find patients suitable for this technique only if: (1) the ascending aorta is rightward (more than one half located on the right in respect to the right sternal border) at the level of the main pulmonary artery, (2) the distance between the ascending aorta and the sternum does not exceed 10 cm, and (3) the angle between the midline and the inclination of ascending aorta (α angle) is larger than 45°[10]. These CT selection criteria differ somewhat from those recommended by Glauber *et al.*[10]. First, the 3-D CT reconstruction of the distance from the mid-clavicular line of the second and third intercostal spaces to the origin of the right innominate artery is of utmost importance in this protocol. The shorter this distance is, the safer the central arterial cannulation. Second, beside the configuration of the chest 3-D CT measurements of the distance from the mid-clavicular line of the second and third intercostal spaces to the aortic valve annulus are mandatory for estimation of the ease of the valve procedure itself. Thus, selection of patients for this protocol is based on two key distances, *i.e.* working distances to the aortic valve and the central arterial cannulation site. As a consequence, the criteria of distance from the intercostal space to the aortic annulus and the aortic cannulation site give more precise information and are more helpful for selection and pre-operative planning of patients than the formulation of distance of ascending aorta to the sternum used by Glauber and co-workers[10]. Other groups do not routinely use CT measurements for selection of patients for right anterior mini-thoracotomy[16,17,18]. However, in order to compensate for skipping this step, these authors manage a dislocation of the ribs during entry to the pleural space followed by refixation of the dislocated rib(s) with a plate at the end of the operation[16,17,18]. However, this strategy may reduce patient comfort and could potentially lead to more bleeding from broken bone surfaces.

An important aspect of the present protocol is that the arterial perfusion is done through central aortic cannulation. The site of arterial perfusion during minimal access heart valve surgery in general, and during right anterior mini-thoracotomy in particular, remains controversial. While a number of centers and surgeons have reported an increased risk of stroke following peripheral femoral arterial cannulation as compared to central aortic cannulation[19,20], other authors have reported an increased risk of stroke following central aortic cannulation[21], or no difference is reported between the two strategies[22]. This disparity might be due not only to different definitions of stroke, but also to associated comorbidities such as older age and peripheral arterial vascular disease[20,23]. Other potential complications related to peripheral femoral arterial perfusion are infection, lymphoid fistula, arterial wall dissection, and distal limb ischemia[24]. In contrast to Glauber and colleagues, who used short-tipped aortic cannulas for central aortic cannulation[25], we used commercially available arterial cannulas long enough so that the tip of the cannula could be placed at the origin of the descending aorta. The rationale of this strategy is to avoid the jet of the arterial perfusion into the aortic arch with potential dislocation and embolization of the arch vessels.

In this protocol, we gain access to the pleural space and the heart without deliberate fracture or dislocation of the ribs, in contrast to other protocols[16,17,18]. Based on copious experience, a gentle and gradual opening of the spreader avoids inadvertent fracture of the ribs. In the same line of tissue preservation, we do not systematically ligate the right internal thoracic vessels and reserve the ligation for anatomical variations of these vessels where they are laterally more than 1 cm to the right of the sternal edge. Systematic fracture of the ribs could potentially increase the amount of bleeding from the fractured bone surfaces and cause patients discomfort, despite the fixation at the end of the operation[25].

Early mortality of patients operated on according to the present protocol of right anterior mini-thoracotomy (1.5%) compares favorably with those undergoing full sternotomy (1.8%) (**Table 4**) and with the reported outcomes for isolated aortic valve replacement in the STS Database (2.4%)[26]. Compared to full sternotomy, right mini-thoracotomy did not increase early postoperative complications, including reoperation for bleeding and stroke. The rate of reoperation in the two groups of patients (RAMT 2%, FS 2.3%) was slightly less than that reported in the STS database (3.9%), whereas the incidence of stroke was slightly higher (RAMT 2.6%, FS 3.5%, STS 1.1%)[26]. The reason for this difference might lie in the definition of stroke used in these patients and in the STS Database. In this protocol, all clinically diagnosed peri-operative cerebrovascular events, including reversible transient deficits were computed as stroke, while the STS Database reported on permanent stroke[26]. Further, in the studied patients, the incidence of new onset atrial fibrillation was reduced by RAMT approach (18%) compared to the FS group (30%, p=0.02) and the STS Database (31%)[26]. This finding is in accordance with the study of Glauber *et al.* reporting 18.1% and 27.9% of new onset atrial fibrillation in RAMT versus FS patients (p = 0.03)[27]. This difference might be due to the elimination of direct cannulation of the right atrium in the RAMT compared to the FS approach. In fact, the scar of the cannulation site of the right atrium may be the local origin of atrial arrhythmias. This hypothesis warrants further investigation. Another improvement in early patient outcomes achieved by the RAMT (0%) compared to FS approach (1.2%, p=0.02) was the disappearance of deep wound infection. In comparison to FS, RAMT access significantly lowered the need for pain medication and transfusion requirements in this protocol. As a result of reducing the incidence of post-operative new onset atrial fibrillation, transfusion requirements, and deep wound infection, as well as of enhancing patient comfort by reducing pain medication, the RAMT approach significantly shortened the length of hospital stay as compared to the FS approach. This observation is in accordance with other studies reporting similar reduction in the length of hospital stay, which could potentially contribute to cost savings[16,27].

In this protocol, excision of the aortic valve and implantation of the new valve prosthesis remain unchanged compared to the full sternotomy. This may explain the achievement of the same good results of conventional AVR through full sternotomy, and makes this approach an attractive alternative to TAVI in the intermediate risk subgroup of patients[28].

The limitations of the comparisons between the RAMT and FS cohorts in this protocol are due to the retrospective nature of these data. Although the risk profiles of the two groups reflected by Euroscore[15] were comparable between these groups, other uncontrolled parameters might have affected the reported comparison. The limitations of the reported technique in this protocol are represented by the optimal CT measurements and other criteria reported in **Table 1**. In these patients, aortic valve replacement should be performed by conventional full or partial sternotomy access.

In conclusion, right anterior mini-thoracotomy as described in this protocol can be done in selected patients according to the described criteria with comparably good results achieved with the full sternotomy approach. The additional operative times required are not detrimental to the patients and are rewarded by improved patient comfort and accelerated early recovery. This minimally invasive approach can be a viable alternative to TAVI in intermediate risk patient populations needing an aortic valve replacement.

Disclosures

The authors have nothing to disclose.

Acknowledgements

This work was supported by a grant (N° 32119) of the Swiss Cardiovascular Foundation to RT.

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